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Correlation Between Surface Temperature of Major Muscle Group and Swimming Training Level Based on Infrared Thermal Imager

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Abstract

The purpose of this article is to study the relationship between body temperature and training level and muscle load in different swimming styles by using infrared thermal imager. 21 male swimmers aged 18-28 were recruited for the experiment. They were divided into three groups: beginner group (FINA point under 190), amateur group (FINA point between 222 and 337) and high-level group (FINA point between 367 and 710). Each experiment session included 20 minutes workout and 50-meter freestyle simulated competition in a 50-m standard swimming pool. Conclusion: 1) The temperature of muscle group changed significantly before and after swimming, the muscle involved in exercise and the heat production increased can improve muscle strength and contraction speed and prevent sports injury. 2) The higher the swimming training level of the subjects, the more accurately the corresponding muscle groups can be mobilized to participate in the completion of various swimming technical requirements. 3) Positive relationship between surface temperature of major muscle group and swimming training level, the higher the swimming training level of the subjects, the more active the body mobilized muscle activity.

Keywords

Infrared thermal imaging, Swimming, Surface temperature of major muscle group, Swimming level.

1. Introduction

Infrared thermography is a non-contact temperature measurement and non-destructive testing method, which is widely used in electric power, industry, clinical research and other fields. In recent years，scholars have gradually applied infrared imaging to the field of sports medicine. Researchers stated that biological heat transfer equation described changes in tissue metabolism and blood supply during human movement [1] which directly led to changes in heat production, and the temperature field of living organisms also changed. Infrared imaging can capture subtle changes in temperature, such as peripheral blood flow [2], diabetic foot complications [3], evaluation of the efficacy of exercise prescription in patients with diabetes [4,5]. This technique has also conducted research on thermoregulation inyoga, tai chi etc. [6].

During exercise, the material metabolism of human muscle was enhanced, calorie production increased, and through the regulation of the nervous system and the transportation of blood circulation, heat was transmitted to the surface of body, which in turn caused an increase in skin temperature [7]. Bishop [8] explained that for every 1°C change in muscle temperature, muscle contraction was increased by 2-5 %. Therefore, the change of temperature of muscle

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surface reflects the ability of muscle response during exercise, and the regulation of muscle surface temperature during exercise is closely related to training level. The application of infrared thermography on monitoring how surface temperature of muscle in swimming is an interesting research topic.

In this study, infrared thermo-image equipment was used to test the surface temperature of muscle

groups in athletes with different swimming levels, and analyzed the relationship between different

training level and the response of related muscle groups. To explore the changes of surface

temperature of major muscle groups in freestyle swimming, so as to provide more information about athletes' training.

2. Materials and Methods

2.1. Subjects

21 male swimmers in the university swimming team joined the experiments (Table.1), swimmers

were equally divided into three groups: beginner group (FINA point under 190), amateur group (FINA point between 222 and 337) and high-level group (FINA point between 367 and 710). All subjects are informed of the purpose of the experiment, the procedure and the precautions during the experiment before starting to ensure the smooth progress of the experiment.

Table 1. Information about subjects

Group	Age	Hight (cm)	Weight (kg)
Beginner group (n=7)	21±2.89	174±5.24	71±13.84
Amateur group (n=7)	20±0.82	174±4.01	71±5.86
High-level group (n=7)	20±2.52	182±5.89	72±6.15

2.2. Equipment

One medical thermal imaging camera was used during experiments. It was produced by Guangzhou Seaory Infrared Co., Ltd., China, with a temperature resolution of ≤0.05°C/30°C and an image resolution of 380×488. All the test were conducted in a 50-m swimming pool with 25°C water temperature and 70% humidity in the environment.

2.3. Experiments Protocol

Experiments were carried out group by group. Athletes were asked to join two experiment tests in total. The first test: subjects were asked to rest for 15 minutes before taking thermal images. Athletes stood only in swimming suits, with the standard anatomical posture of the human body. Then used infrared thermal imager to collect temperature of the surface of main muscle groups included deltoids, rectus abdominis, pectoralis major, latissimus dorsi, biceps, triceps, quadriceps, biceps femoris [9]. The second test: After 30 minutes of individual warming up (both dry-land and under water) and 10 minutes of rest, subjects were asked to take one simulated 50 meter freestyle test with maximum speed. After the simulated test, the moisture left on the surface of the skin was immediately wiped dry, subjects were asked to take the second thermal image of major muscle groups directly, without cooling down.

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3. Results and Discussion

3.1. Surface temperature analysis of major muscle groups at rest

The surface temperature of the eight muscles of the subject was collected by using an infrared camera in the quiet state of the subject (Table 2), that the average temperature of different muscle groups was slightly different. High-level group showed the highest average surface temperature of each muscle group, amateur group with the lowest.

Table 2. Surface of average temperature of major muscle groups (°C)

	Biceps femoris	Quadriceps	pectoralis major	Rectus abdominis muscle	latissimus dorsi	deltoid	triceps	Biceps
Beginner group	35.5±0.8	34.8±1.4	35.0±0.6	34.6±2.1	34.8±0.9	34.4±1.9	34.1±1.0	35.2±1.1
Amateur group	33.7±2.0	33.7±2.7	34.1±1.9	34.0±2.5	33.8±1.7	34.0±1.7	34.1±2.0	34.2±1.6
High-level group	34.2±1.4	34.4±1.8	36.7±5.6	35.0±1.8	35.2±1.3	35.7±0.6	34.9±1.1	35.4±0.9

The average skin temperature was measured by the '8-point temperature measurement method'[10,11], the measurement points were quadriceps, biceps femoris, pectoralis major, rectus abdominis, latissimus dorsi, deltoid, triceps, biceps, the corresponding weighted coefficients were 0.19, 0.2, 0.15, 0.12, 0.15, 0.6, 0.7, 0.6, 0.6, and the calculation formula was: Tsk=0.19 quadriceps + 0.2 biceps + 0.15 pectoralis major + 0.12 rectus abdominis + 0.15 latissimus dorsi + 0.6 deltoid + 0.7 triceps + 0.6 biceps. After analysis, it concluded that there was no significant difference in the body surface temperature of the main muscle groups of all the subjects ($p>0.05$) (Table 3). Meaning the body temperature of subjects in three groups were relatively similar in a quiet state, the main muscles did not participate in any exercise yet, so it is reasonable to concluded that there was no significant difference in the table temperature of the main muscle groups of the three groups.

Table 3. Relationship between muscle surface temperature of three groups at rest state

Group	Number	Sum	Average	Deviation		
Beginner group	7	663.674	94.8106	6.2157		
Amateur group	7	657.956	93.9937	6.493		
			Cont. Table 3			
High-level group	7	636.137	90.8767	18.4473		
	SS	df	MS	F	P-value	F crit
Deviation between groups	60.3357	2	30.1679	2.9048	0.0806	3.5546
*: P<0.05;	**: P<0.01					

3.2. Intra-group comparative analysis of table temperature changes in major muscle groups in swimming

Fig. 1, Fig. 2 and Fig. 3, higher-level group showed smallest magnitude of the decline of the decrease in surface temperature of each muscle groups. The average temperature of the Biceps

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femoris in the high-level group was lower than that of the beginner and amateur groups, but the average surface temperature of the other muscle groups was higher than that of the other two groups. In the beginner group, the surface temperature of the other muscle groups changed significantly between the first and the second test except deltoid muscle, while the temperature of the quadriceps muscle changed the most in Fig. 1.

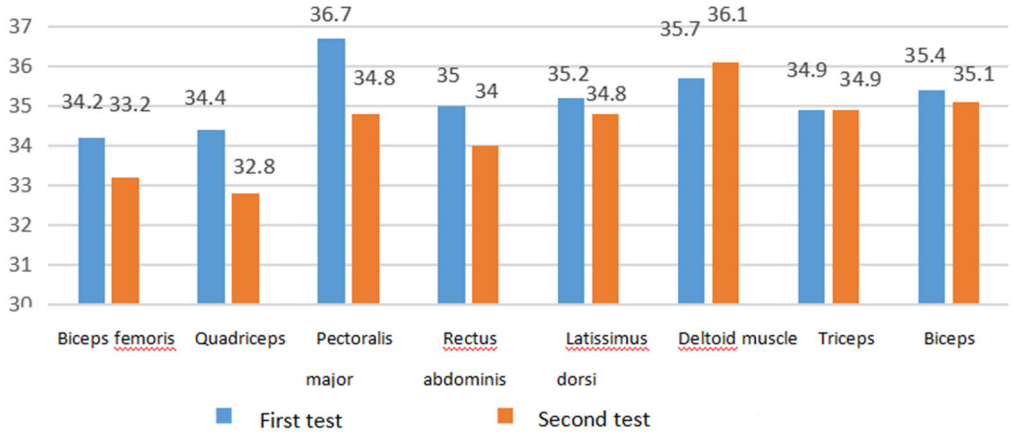

Figure 1. Surface temperature of muscle groups of Amateur group

The surface temperature of the deltoid muscle increased of the second test, while the surface temperature of the other muscle groups showed different amplitudes of decrease, among which the temperature of the rectus abdominis muscle changed the most (Fig. 2). The surface temperature of the deltoid muscle in the high-level group was higher than the temperature int the first test, while surface temperature of the triceps was basically consistent between the first and second test, and the temperature of the latissimus dorsi and biceps tests was close to the temperature among two tests (Fig. 3).

After the simulation test, major muscle groups were tested after the subjects wiped off the moisture on the surface of the skin. Analysis found out that the temperature of most of the muscle groups decreased after simulated test. Due to water has thermal conductivity, part of the body's heat was lost in the water when athletes swim, so that the body temperature is reduced. Since the skin is closely related to local blood flow, various of factors can affect skin vasoconstriction, such as environmental temperature changes or mental tension etc, which can change the temperature of the skin [12].

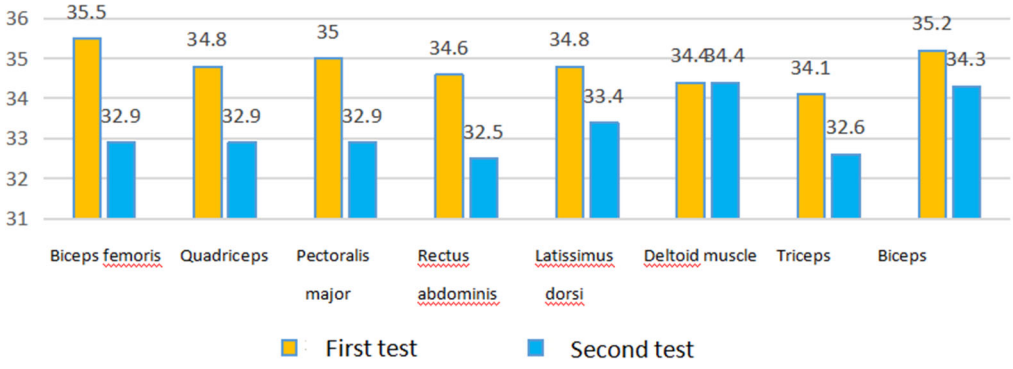

Figure 2. Surface temperature of muscle groups of Amateur group

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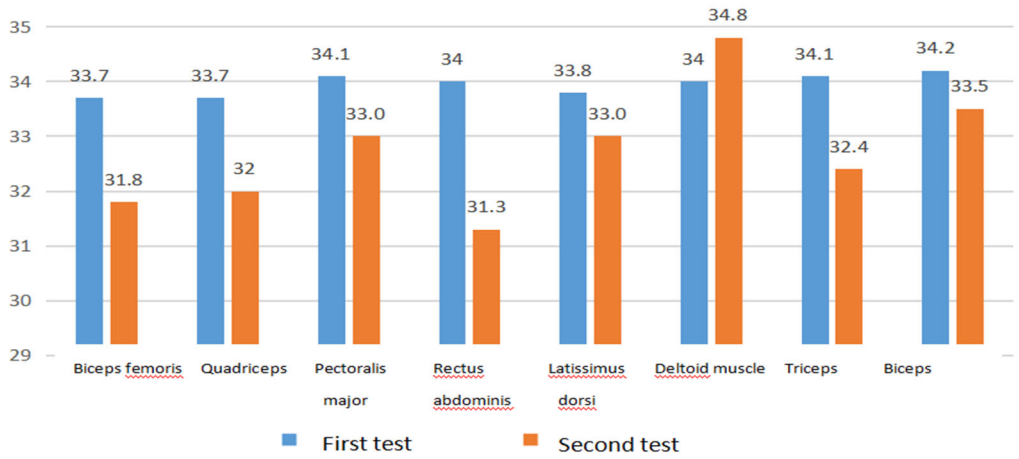

Figure 3. Surface temperature of muscle groups of High-level group

The amount of radiated heat of the body mainly depends on the temperature difference between the skin and the surrounding environment, followed by the heat dissipation area of the skin, the more the skin temperature is higher than the ambient temperature, the more heat the body radiates, the larger the skin area, the more heat radiated. In the process of medium-intensity and high-intensity fixed compound exercise, the body surface temperature showed a change trend in three stages: decrease-rise-balanced [13]. Therefore, the surface temperature of the main muscle groups of each group decrease to varying degrees were taken into consideration.

In order to explore whether there are individual differences in the temperature changes of the table temperature of major muscle groups in the same group. There was significant differences among two tests in the beginner group ($p < 0.5$) (Table 4), indicating that subjects in beginner group lost more heat, and the change of temperature was obvious. Since high-intensity exercise stimulated muscle activity to increase the body's metabolic level, ATP is explained by energy, and the body's calorie production was increased [14]. When muscle produced increasing energy, heat was transmitted to the body surface through blood circulation, resulting in an increase of skin sueface temperature [15]. When subject did not fully stimulate the muscle groups, relevant muscle group did not produce enough energy, their body failed to produce enough heat, with the influence of water temperature. Which may explain the reason why the surface temperature of major muscle groups in beginner group dropped significantly.

Table 4. Temperature between two tests in Beginner group

Test	Number	Sum	Average	Deviation		
First test	7	657.956	93.994	6.493		
Second test	7	634.804	90.686	4.646		
	SS	df	MS	F	P-value	F crit
	38.287	1	38.287	6.874	0.022*	4.747

The data of the amateur group showed that there was a significant difference in individual subjects ($p<0.5$) (Table 5), indicating that in amateur group, some of the subjects could not fully stimulus major muscle groups to swim. Therefore, the change in surface temperature of the main muscle groups partly reflects that the training level of subjects in the amateur group needs to be improved.

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Table 5. Temperature between two tests in amateur group

Test	Number	Sum	Average	Deviation		
First test	7	828.926	92.103	20.311		
Second test	7	799.062	88.785	5.904		
	SS	df	MS	F	P-value	F crit
	49.54769	1	49.548	3.780	0.049 *	4.494

There was no significant difference in the high-level group (P>0.5), indicating that the subjects in the high-level group had an average of training level, and basically fully mobilized all the muscles during simulation competition (Table 6). When major muscle groups kept exercising, the metabolism of muscle tissue became larger, the heat production increased, the higher energy production was. The higher the level of swimming training of the subjects showed a stronger ability to maintain a constant body surface temperature compared to other groups. The more accurate body function can be to correspond muscle groups to participate, especially in the stimulate completion, which can lead to better swimming performance.

Table 6. Temperature between two tests in High-level group

Test	Number	Sum	Average	Deviation		
First test	7	663.674	94.811	6.216		
Second test	7	658.693	94.099	14.810		
	SS	df	MS	F	P-value	F crit
	1.722	1	1.722	0.168	0.688	4.747

4. Conclusion

1)There is a positive correlation between major muscle group surface temperature and swimming training level. 2) Before and after swimming, muscles produced more heat, the temperature of major muscle group significantly varied, which can increase muscle power and decrease contraction time, as well as preventing injuries. 3)The higher the subject's swimming training level, the more accurately he can mobilize the corresponding muscle group to participate in various swimming posture technical requirements. The higher the level, the more mobilized muscle activity proactively, precise, hence the more pronounced the temperature rises.

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